

Homograft Aortic Valve Replacement: The Subcoronary and Cylindrical Techniques

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Aortic valve replacement using the homograft valve has an important place in the cardiac surgical armamentarium. Despite this, the homograft valve is still not widely used, in part due to the perceived difficulty of the procedure compared with aortic valve replacement using prosthetic devices, less convenient availability of the homograft compared with that of prosthetic devices, and concerns regarding homograft valve failure. This section outlines the subcoronary technique (and its variations) and cylindrical technique for aortic valve replacement using the homograft aortic valve.

Homograft aortic valves had a short investigational¹ and clinical² application by insertion in the descending thoracic aorta. However, it was Ross³ who first performed a homograft aortic valve replacement in the orthotopic position using a single suture line technique based on the work of Duran and Gunning.⁴ In the same year, working independently, Barrett-Boyes⁵ also described the subcoronary technique using a double suture line method.

The sources of homograft aortic valves include organ donors where the heart is not being used for transplantation, autopsies (within 24 hours of death) and excised cardiac transplant recipient hearts. There is obviously a need for sterilization and storage of homograft aortic valves and a discussion of these aspects is beyond the scope of this review. Currently, the preferred method of sterilization is by incubation with pharmacological doses of antibiotics and storage by cryopreservation at -196°C .

Like all tissue valves, homograft aortic valves may fail. An understanding of the mechanisms of homograft valve failure and the way in which these mechanisms interact has important surgical implications. There are a number of mechanisms of homograft valve failure and what is also of importance is the way in which these mechanisms may interact. Homograft aortic valves may develop progressive regurgitation as a result of a change in the mechanical properties of the leaflets over time (loss of leaflet extensibility in the radial direction).⁶ This loss of leaflet radial extensibility of the homograft is an exaggeration of the normal change in the mechanical properties of leaflet tissue due to aging. This loss of radial extensibility results in a progressive decrease in the area of leaflet coaption. Homograft valves may fail because of leaflet degeneration characterized by thin-

ning, tearing, and perforation,⁷ and also leaflet calcification,⁸ all of which may in part be due to an immunological response. Homograft valves may also fail due to geometric distortion related either to the insertion technique used or other factors such as aortic root geometry, technical factors, and surgical experience. Progressive dilation of the host aortic root may also result in regurgitation of the homograft aortic valve. When thinking about homograft valve failure, it is important to understand that these mechanisms are interrelated and each mechanism may be influenced by a number of known risk factors for homograft valve failure (Figure 1).⁹⁻¹³ For example, if an older donor valve (older donor age is a risk factor for homograft valve failure) that has lost radial extensibility is implanted by the subcoronary rather than the cylindrical technique⁹ in a patient with a large aortic root diameter,¹¹ the likelihood of adequate long-term leaflet coaption may be significantly reduced.

The evolution of surgical techniques for homograft aortic valve implantation to deal with all types of aortic valve and aortic root pathology is interesting to examine on the background of the mechanisms of homograft valve failure. Failure of homograft aortic valves inserted by the subcoronary technique is probably due in part to geometric distortion of the pillars during insertion. The pillars containing the commissures of the valve must be aligned just as they were in the donor (although the homograft may have some natural asymmetry) and this perfect alignment may not be possible due to distortion of the host aortic root, surgical inexperience and technical factors, for example, allowing the pillars on each side of the aortotomy to approximate each other during aortotomy closure. It is for this reason that modifications of the subcoronary technique arose, including insertion of a pericardial patch¹⁴ in the lower end of the aortotomy to prevent approximation of the pillars during aortotomy closure, and the use of the subcoronary technique with retention of the noncoronary sinus to maintain the geometric relationship of the two commissures on each side of the aortotomy.¹⁵ Of course, the tendency for postoperative homograft regurgitation because of pillar malalignment with the subcoronary technique is exacerbated by insertion of the valve in a larger aortic root as well as the process of accelerated loss of radial extensibility of the leaflet

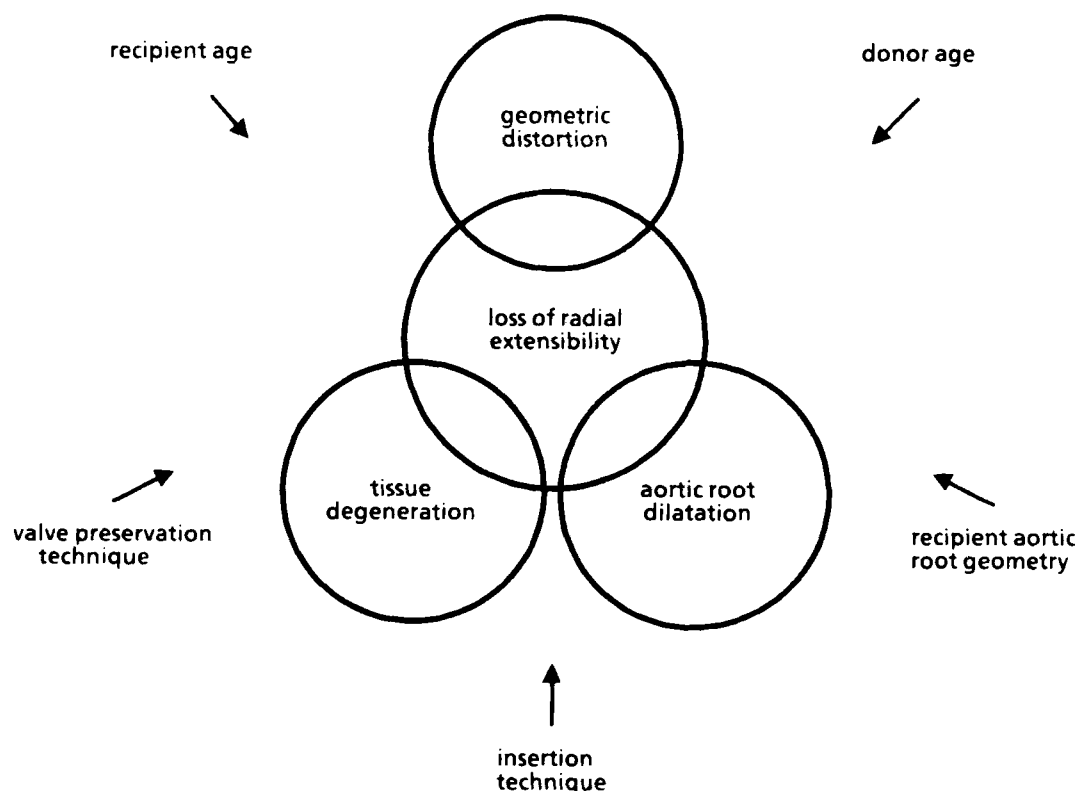


Figure I. A depiction of the interrelationships between the overlapping mechanisms of homograft valve failure influenced by known risk factors: (younger) recipient age,^{9,10} older donor age,^{9,10} (larger) aortic root diameter,⁹ insertion technique,^{11,12} and valve preservation technique.^{9,10} Although compiled from a series of cryopreserved and antibiotic sterilized valves, these risk factors may play a role in failure of either type of valve. (Reprinted with permission from McGiffin DC: Invited letter concerning: leaflet viability and the durability of the allograft aortic valve. *J Thorac Cardiovasc Surg* 108: 988-990, 1994.)¹³

tissue. With the realization that proper alignment of the commissures of the homograft was critical to homograft valve competence, the cylindrical (or mini-root) technique in which the homograft is inserted in the aortic root as a unit^{14,16} was developed. Despite all the variables involved in homograft valve failure as outlined above, there is evidence that the long-term competency of the homograft aortic valve inserted by the cylindrical technique is superior to that of the subcoronary technique.^{17,18} As a further extension of the concept of insertion of the homograft as a competent unit, there is interest in using the aortic root replacement technique (which has traditionally been reserved for aortic root disease, extensive destruction of the aortic annulus by endocarditis and left ventricular outflow tract obstruction) for aortic valve replacement,¹⁹ although the evidence to support this position is still not available.

The indications for aortic valve replacement using a homograft aortic valve at the University of Alabama at Birmingham are for active aortic valve endocarditis (native or prosthetic) and the tissue valve of choice for

patients between the ages of approximately 30 to 60 years. Below the age of 30 years the pulmonary autograft would be primarily considered and over the age of 60 years a xenograft valve would likely be implanted.

The homograft aortic valve can be used for the full range of aortic valve and aortic root pathology no matter how severe the aortic root destruction in the case of endocarditis or asymmetric the aortic root may be. Perhaps the only possible contraindication to the use of the homograft valve is in patients with coronary ostia that are 180° apart, although a method has been described²⁰ to accommodate a homograft by remodeling the geometry of the aortic root. For patients with aortic valve disease, the homograft aortic valve is inserted at the University of Alabama at Birmingham and in most other centers using either the cylindrical technique or by aortic root replacement. There is currently very little need to use the subcoronary technique, with perhaps the only indication being for the small aortic root (less than approximately 21 mm) where the magnitude of geometric distortion of the pillars would be less pronounced than in a larger aortic root.

SURGICAL TECHNIQUE

After the insertion of the usual monitoring devices, including an intraoperative transesophageal echocardiogram transducer, either a median sternotomy or a limited access ministernotomy (dividing the manubrium and the body of the sternum for one to two intercostal spaces), is performed. Cardiopulmonary bypass is established with a single cannula in the ascending aorta and a two stage cannula through the right atrial appendage. A left ventricular vent is inserted through the right superior pulmonary vein. Moderate hypothermia to 28°C is used, as well as the usual methods of myocardial protection delivered by direct coronary cannulation. The aortotomy is transverse and then curves down into the noncoronary sinus. The transverse part of the aortotomy should be a few millimeters downstream from the incision that would normally be employed for

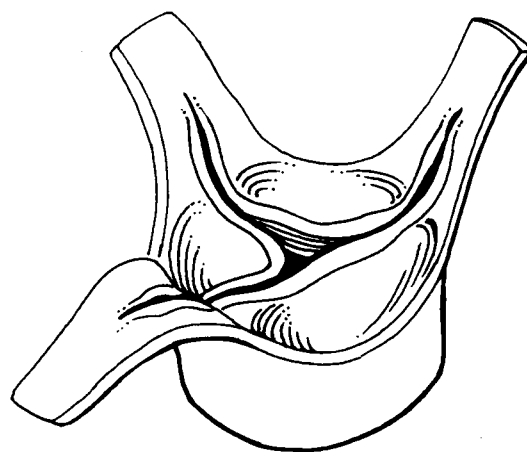
the insertion of a prosthetic valve. This is to avoid the situation of pillars, in the case of the subcoronary technique, or to prevent the upper rim of a homograft cylinder from overlapping the transverse portion of the aortotomy. Stay sutures are then placed on the edge of the aortic incision. The aortic valve is excised and the annulus decalcified. It is important to carefully inspect the anatomy of the aortic root, particularly if a subcoronary technique is being used. If there is any asymmetry of the host aortic root with abnormally placed coronary ostia, then this needs to be taken into account during insertion of the homograft valve. The aortic annulus is sized to select the appropriate homograft. A preoperative aortogram or echocardiogram can be used to approximate the annulus size so that an appropriate range of homografts can be available.

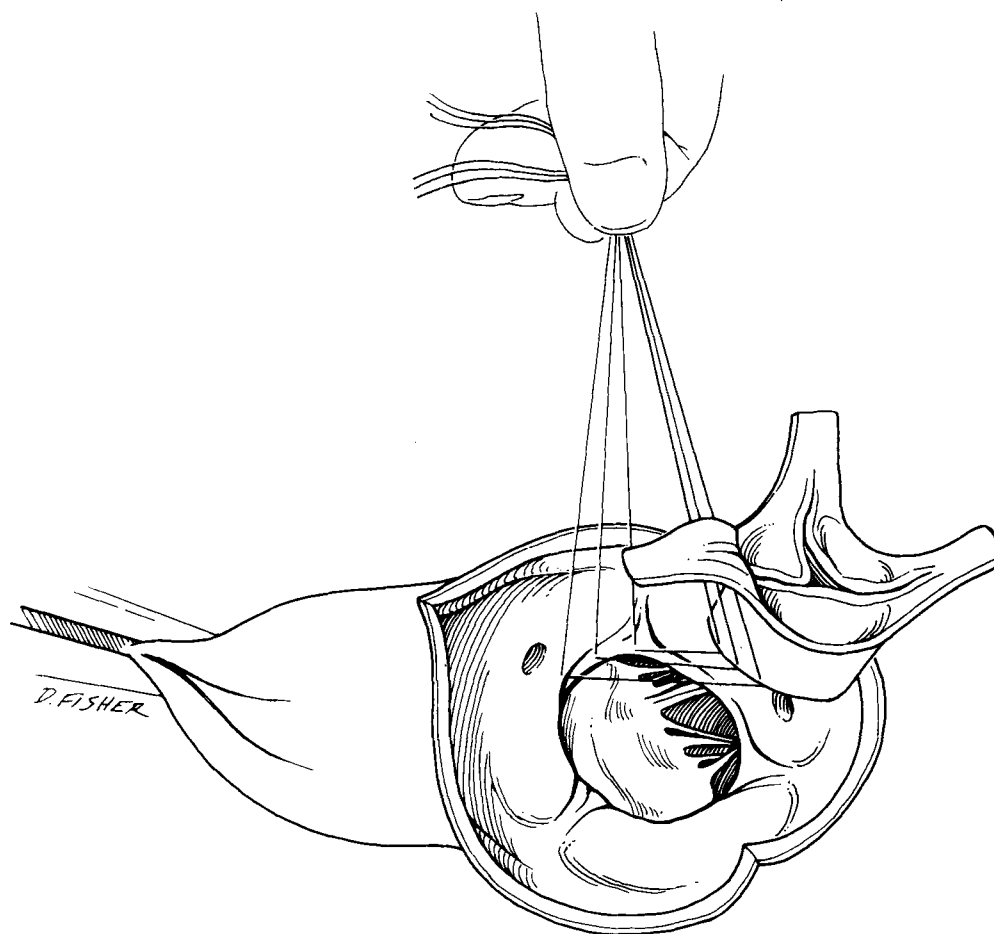
Subcoronary Implantation

It is critical for this technique that the aortic root of the host be symmetrical, that the annulus diameter is very similar to the sinotubular diameter so that the

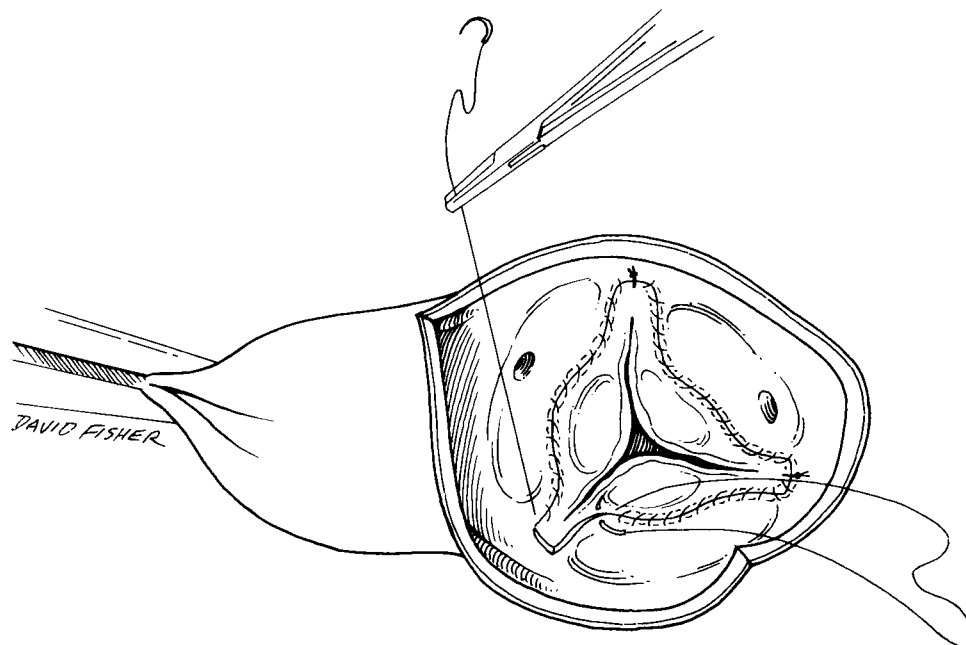
pillar alignment is symmetrical. A homograft valve of the same diameter of the host annulus is selected and thawed.

1.1 The homograft valve is then prepared by trimming the muscle and anterior leaflet of the mitral valve at the base of the homograft to within 2 to 3 mm of the nadir of the attachment of each leaflet. The muscle is trimmed to a thickness of approximately 3 mm. The pillars, which support the commissures of the homograft are then fashioned by excising the aortic wall so that a rim of aorta of the approximately 3 mm in width is left around the attachment of each leaflet. It is important to carefully inspect the homograft valve because any asymmetry of the homograft may dictate the orientation of the valve to accommodate host aortic root asymmetry. Although there has been a fashion to orient the homograft with a 120° counter clockwise rotation, there is no evidence to suggest that this is necessary.



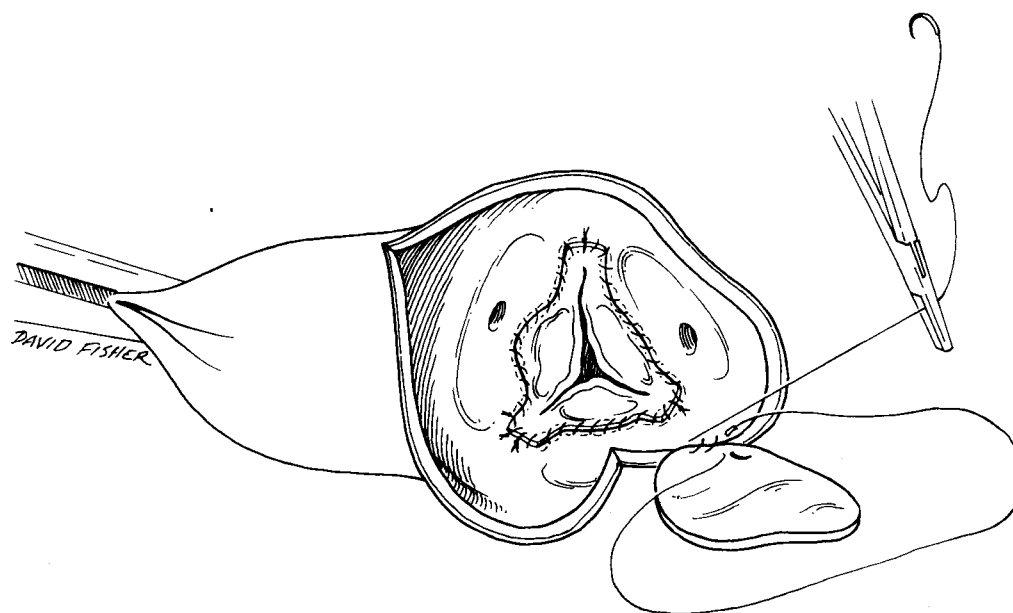


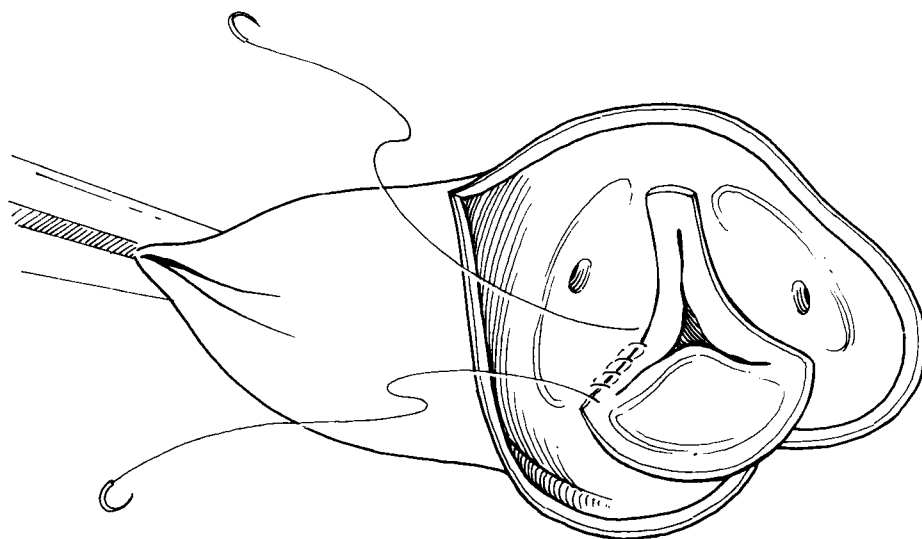
1.2 The lower suture line can be performed by turning the valve inside out, placing the homograft inverted into the left ventricular outflow tract, and performing a continuous lower suture line. However, the preferred technique is an interrupted suture line without inversion using a 4-0 polypropylene suture. The interrupted suture line commences at the base of the homograft directly below the commissure between the left and right leaflets, and each suture is in turn held by the assistant. It is important to note that the lower suture line is horizontal, except in the region of the membranous septum. Therefore, the sutures do not follow the scallops of the host annulus. After completion of the left coronary sinus, in a similar manner, the right coronary lower suture line is performed working from the commissure between the left and right leaflets toward the commissure between the right and noncoronary leaflets. In the region of the membranous septum the sutures are placed just beneath the annulus, rather than horizontally. Following completion of the right coronary sinus, the noncoronary sinus sutures are placed working in the same direction. The homograft is then lowered into the aortic root and each suture is tied, in turn working in the same direction in which the sutures were placed.



1.3 The upper suture line is then performed by using a separate suture of 4-0 polypropylene for each scallop. It is important during the performance of the upper suture line that the pillars are oriented so that the pillar alignment is perfect. The pillars on each side of the aortotomy may need to be deviated slightly apart to prevent the tendency for malalignment by aortotomy closure. The left coronary sinus scallop suture line is performed first commencing at the deepest point of the sinus. The continuous suture line is passed through the homograft wall and adjacent host aortic wall to the top of each pillar. Similarly, the right coronary distal suture line is performed followed by the noncoronary distal suture line. The sutures are then tied at the top of each pillar. The aortotomy is then closed with continuous 4-0 polypropylene. The usual methods of thorough deairing are performed followed by reperfusion and separation from cardiopulmonary bypass.

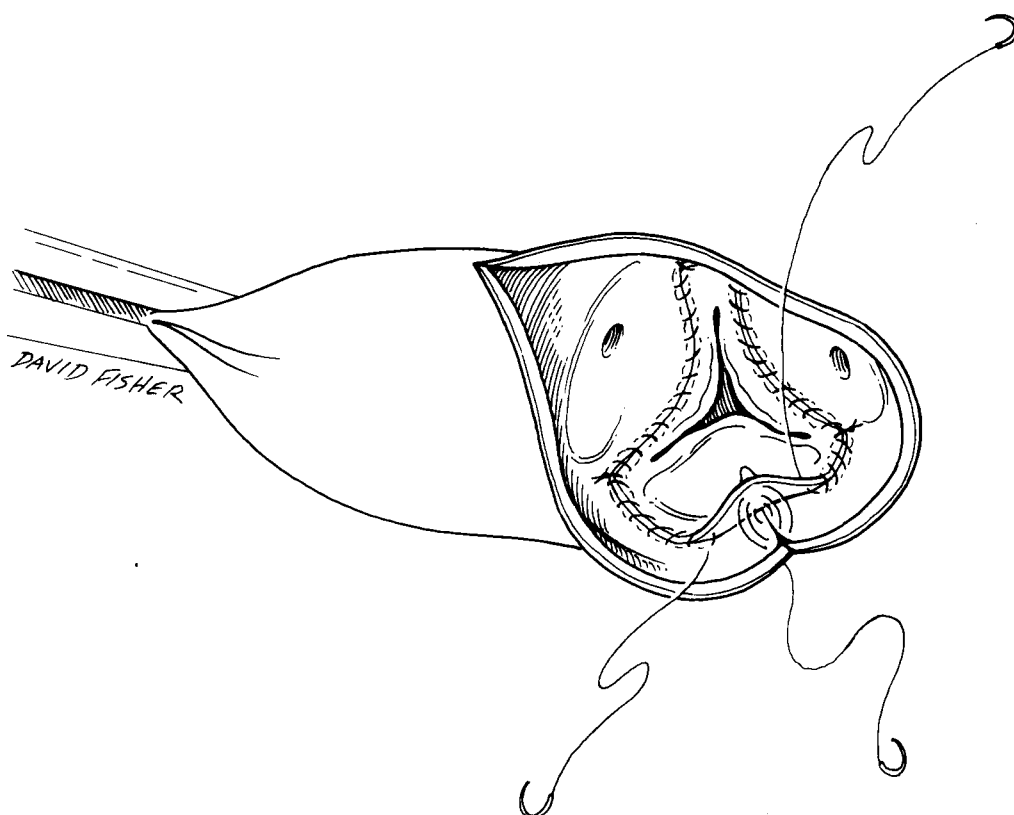
1.4 If the pillars on each side of the aortotomy deviate excessively toward each other during aortotomy closure, then a pericardial patch may be placed in the lower end of the aortotomy suture line to prevent this. The size of the pericardial patch needs to be judged accurately and should be large enough to compensate for the loss of distance between the pillars due to aortotomy closure.





1.5 The technique of subcoronary implantation with an intact noncoronary sinus of the homograft is a variation devised to maintain the geometric relationship between the commissures on each side of the aortotomy. The homograft valve is trimmed in the same way as for the subcoronary technique, except that the noncoronary sinus is left intact. The lower suture line and the upper left and right coronary sinus suture lines are performed in the same way as for the subcoronary technique.

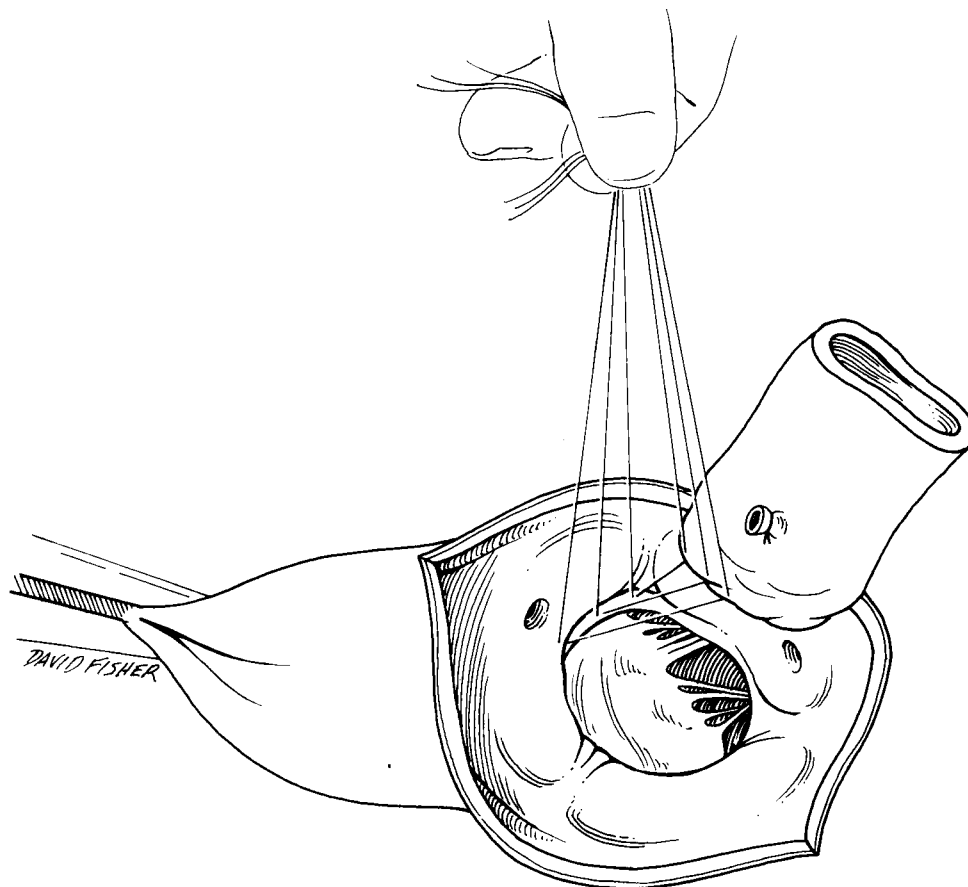
1.6 The lower end of the aortotomy is closed with the sutures passing through the homograft adventitia in the noncoronary sinus. Before the aortotomy is completely closed, the upper margin of the noncoronary sinus is sutured to the host aortic wall.



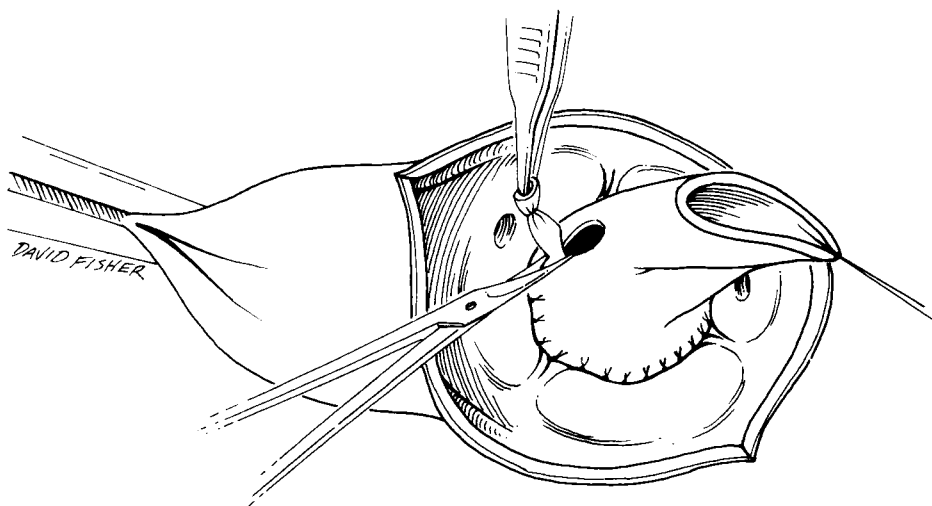
Cylindrical Implantation

In contemporary practice, the cylindrical technique is performed considerably more frequently than the subcoronary technique. After excision of the native aortic valve and sizing, a homograft valve is selected. Because

the homograft is implanted as a unit, the size of the homograft is not as critical as it is for the subcoronary technique. A homograft up to 3 to 4 mm in diameter smaller than the host diameter can be selected.

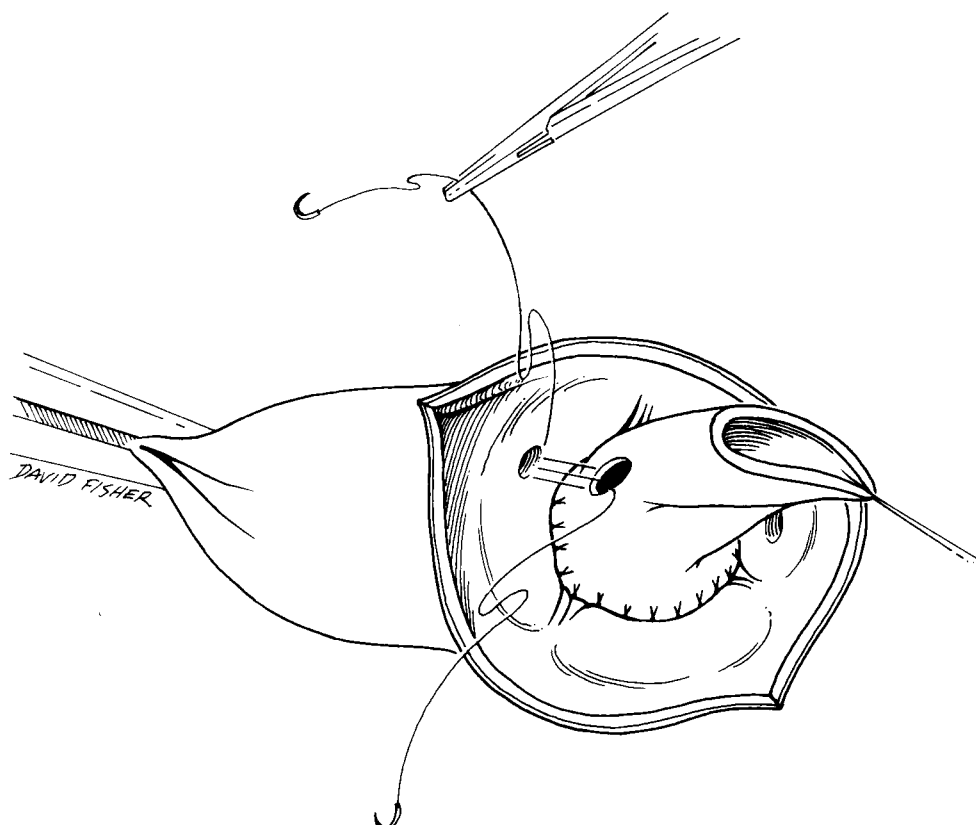


2.1 The lower suture line is performed in the same way as for the subcoronary technique. After placement of the sutures, the homograft is lowered into the aortic root and the sutures are tied and cut.

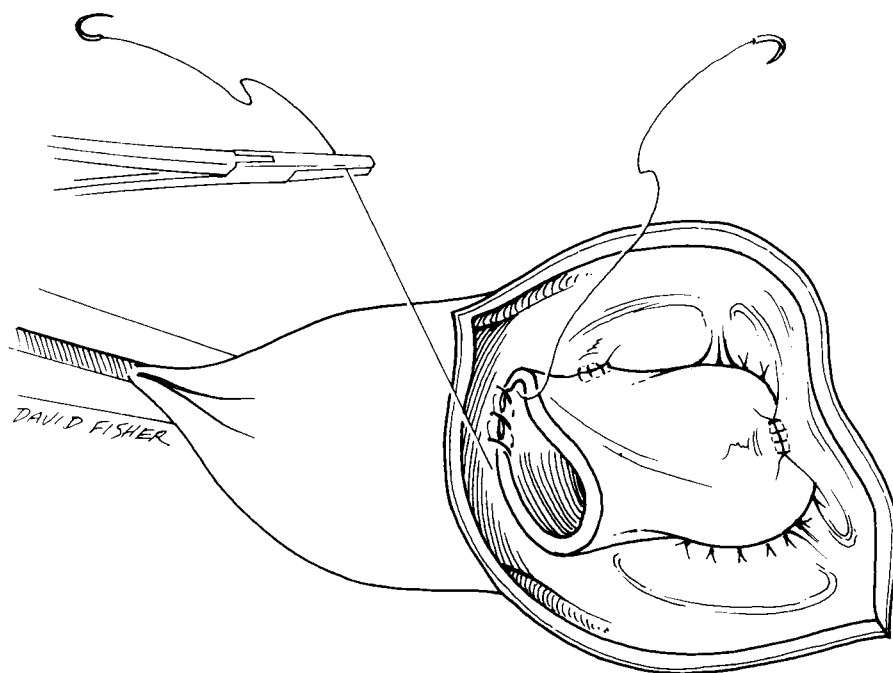
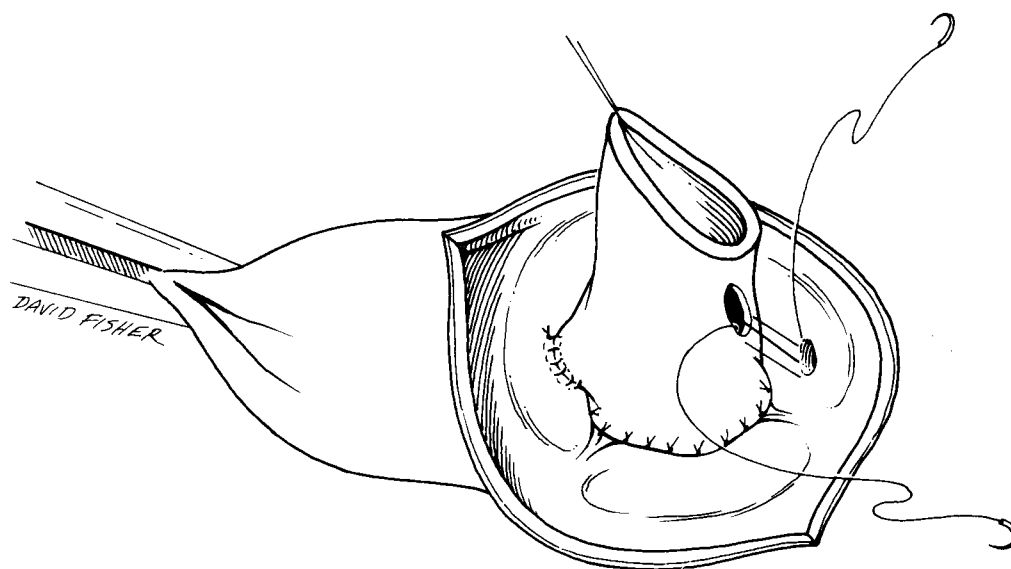


2.2 The left coronary anastomosis is then performed. Usually the left coronary ostium of the homograft can be removed in creating the hole for the anastomosis. However, there will be occasions when the left coronary ostium of the homograft is displaced in a cephalad direction and is not at the same level as the host coronary ostium. Under these circumstances, the hole in the homograft is made below the left coronary ostium and the homograft left coronary ostium is oversewn. The hole in the homograft wall should be 2 to 3 times larger than the native coronary ostium.

2.3 The anastomosis is performed with continuous 5-0 polypropylene commencing on the patient's left side running the suture line posteriorly across to the right side and then bringing the other limb of the suture in the same direction anteriorly.



2.4 A hole is then created in the right coronary sinus and the right coronary anastomosis is performed in an identical fashion to the left coronary anastomosis.



2.5 The homograft is then cut to an appropriate length. The upper suture line is performed at the level of the sinotubular ridge. The suture line is performed with continuous 5-0 polypropylene, commencing posteriorly. The suture line is taken in one direction following toward the other direction. Because of the asymmetry of the host aorta (the host sinotubular junction may be larger than the annulus diameter), the suture bites on the host aortic wall will need to be further apart than on the homograft to allow for this discrepancy. The aortotomy is then closed with continuous 4-0 polypropylene.

At the end of the operation, competency of the homograft can be assessed by transesophageal echocardiography. With careful attention to geometric relationships, particularly with a subcoronary technique, the probability of requiring immediate reoperation because of homograft regurgitation should be exceedingly small.

COMMENTS

Postoperative Management and Results

Postoperative management of patients after homograft aortic valve replacement does not differ from that following other valve replacement procedures except that anticoagulation is not required at any time, although the use of low dose of aspirin at a dose of 81 mg per day may be advisable.

Because homograft valves may fail, long-term surveillance is mandatory. Physical examination and transthoracic echocardiography should be performed on an annual basis. As opposed to xenograft valves that may fail rapidly, the time course of homograft valve failure is usually slow. Since endocarditis may occur on a homograft aortic valve, antibiotic prophylaxis at the time of dental operations and "dirty" operations is necessary.

The long-term results of homograft aortic valve replacement are becoming increasingly available. The yardstick by which the durability of tissue valves is judged is the actuarial freedom from reoperation, which, in most series using the cryopreserved homograft valve, is approximately 70% at 15 years. It needs to be understood that because of the effect of censoring

for death, freedom from reoperation by the Kaplan-Meier method assumes that no patients dies. While this is a useful way of depicting durability of a tissue valve, what is perhaps more relevant for the patient is the likelihood that an implanted tissue valve will require re-replacement at some time during the remainder of the patient's life. This information is obtained by the competing outcomes analysis process,²¹ which takes into account the competing risk of death and re-replacement before death. Therefore, the nomogram (Figure II) of the probability of re-replacement before death for patients with xenograft and cryopreserved homograft valves shows that over the age over 60 years there is no difference in the probability of re-replacement before death for cryopreserved homograft and xenograft valves. However, before the age of 60 years the probability of re-replacement of a xenograft valve before the patient dies is significantly greater than the probability of a homograft aortic valve requiring re-replacement before the patient dies.

Currently there are no perfect valve replacement devices. However, the aortic homograft valve has an important role in the management of aortic valve and aortic root disease.

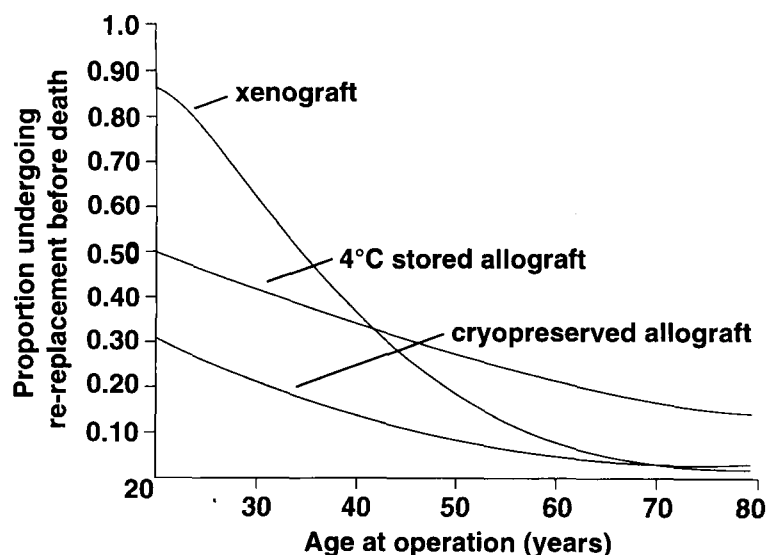


Figure II. Nomogram of the probability of re-replacement before death for any reason for patients with xenograft, 4°C stored, and cryopreserved homograft valves as a function of age at initial valve replacement. The solid lines are the parametric estimates. (Reprinted with permission from McGiffin DC, Galbraith AJ, O'Brien ME, et al: An analysis of valve re-replacement after aortic valve replacement with biologic devices. *J Thorac Cardiovasc Surg* 113:311-318, 1997.)²¹

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